Viking Mission Support

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The support provided to the Viking *Project by the tracking and data system is discussed in the following areas: trajectory design factors, launch/arrival times, look angle between spacecraft, communication range and signal level, solar conjunction, and near-earth phase trajectories.*

I. Introduction

In Space Programs Summaries 37-61, 37-62, and 37-63, Vol. II, the support provided by the tracking and data system (TDS) to the *Viking* Project was described with particular reference to management and organization; technical documentation; and TDS configurations for telemetry, command, and tracking.

The redirection of the Project from 1973 to 1975 has not materially affected these plans, but over the past few months, TDS support activity has been mainly directed toward achieving a better understanding of the influence of TDS capabilities and constraints on the design of the *Viking* 1975 Mission.

The capabilities of the Deep Space Network, as a significant factor in the design of *Viking* 1975 Mars Mission, will be described with reference to the following areas of interest:

(1) Trajectory design.

(2) Space vehicles.

(3) Telecommunications problems.

(4) Navigation accuracy.

(5) Science experiments.

(6) Mission operations.

II. Trajectory Design Factors

Two types of earth-Mars trajectories, namely, the broken-plane type and Type II, are possible for the *Viking* mission after consideration of the 1975 launch opportunity, spacecraft weight, and launch vehicle (*Titan/Centaur*) capability.

Broken-plane trajectories bridge the gap between Type I[1] and Type II trajectories. Broken-plane trajectories permit earth–Mars transfers when it would otherwise be necessary to use single-plane trajectories that would be highly inclined to the ecliptic plane, requiring excessive energy. In the broken-plane trajectories, the spacecraft would make a plane change maneuver from a trajectory very nearly in the earth's orbital plane to a trajectory in Mars orbital plane.

[1]The earth–Mars heliocentric transfer angle is less than 180 deg in Type I trajectories and exceeds 180 deg in Type II trajectories.

By comparison with the broken-plane trajectories, Type II trajectories require fewer midcourse maneuvers and there is some loss of flexibility in launch period. Even though the flight time to Mars is about 1 mo more than the broken-plane trajectories, there is somewhat less risk involved because of the single-plane midcourse maneuvers associated with Type II trajectories.

From the TDS point of view there is no significant advantage of one type over the other, although a slightly longer mission was considered to be a less potential hazard than additional midcourse maneuvers.

In July 1970 these and other trajectory related factors were evaluated and a decision was made to adopt the Type II trajectory.

III. Launch/Arrival Times

The span of launch and arrival dates resulting from this decision are as follows: The launch span would be from August 12 to September 19, 1975 (nominal); and the arrival span would be from July 18 to August 16, 1976 (nominal).

Current TDS planning indicates possible launch periods of November 1975 for *Helios B* and July 1976 for the Grand Tour Jupiter/Saturn/Pluto Mission, a situation which could fully extend the current TDS capabilities for network support (two 85-ft subnets and one 210-ft subnet).

IV. Look Angle Between Spacecraft

The angular separation for two *Viking* spacecraft flying typical Type II trajectories to Mars is shown in Fig. 1 as a function of time from launch. The separation for broken-plane trajectories is similar.

Recognizing that the angular beamwidth of a 210-ft antenna is about 0.1 deg, it is apparent that both spacecraft do not appear in one antenna beam until 7 to 5 days before encounter. In a subsequent article on navigation accuracy it will be seen that several weeks of continuous tracking data are required on each spacecraft prior to Mars orbit insertion (MOI) to realize the desired insertion accuracy. In addition, the demands of the first orbiter and its lander are likely to fully engage each deep space station (DSS) during its view period. These two conflicting requirements preclude the possibility of a DSS time-sharing scheme between the two spacecraft.

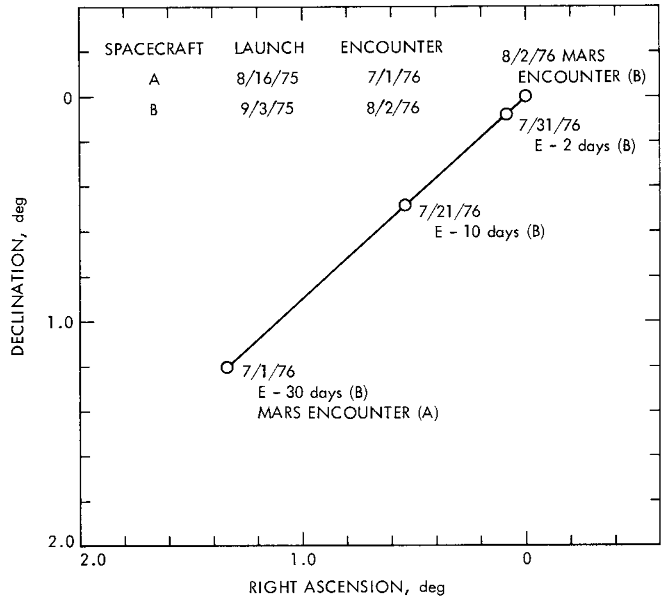

Fig. 1. Relative angular separation of spacecraft B while spacecraft A is in Mars orbit

At present, the navigation and orbital operations requirements are being studied in the hope that an optimum arrangement of separated arrival times and navigation and operations requirements can be found.

V. Communication Range and Signal Level

A typical earth-to-Mars Type II trajectory is shown in Fig. 2, with the corresponding geocentric range and range rate in Fig. 3. The range at encounter is approximately 300×10^6 km and increases to 400×10^6 at maximum range. This has a profound effect in limiting the maximum data rates received by the DSN in comparison with past Mars missions, such as *Mariner* Mars 1969 and 1971. The maximum data rate for the orbiter block-coded telemetry channel is 4 kbps (nominal), while the maximum rate which can be supported by the communications link from the lander is about 250 bps.

VI. Solar Conjunction

Consideration of the Type II earth–Mars orbits proposed for the *Viking* spacecraft shows that earth–Mars conjunction occurs a short time after encounter. A plot of sun–earth–Mars angle as a function of calendar date is shown in Fig. 4 with earth–Mars conjunction occurring on November 25, 1976. As a consequence of the proximity of the radio beam to the solar disk, both uplink and downlink suffer a degradation in performance. The two principal contributors to the degradation are increased system

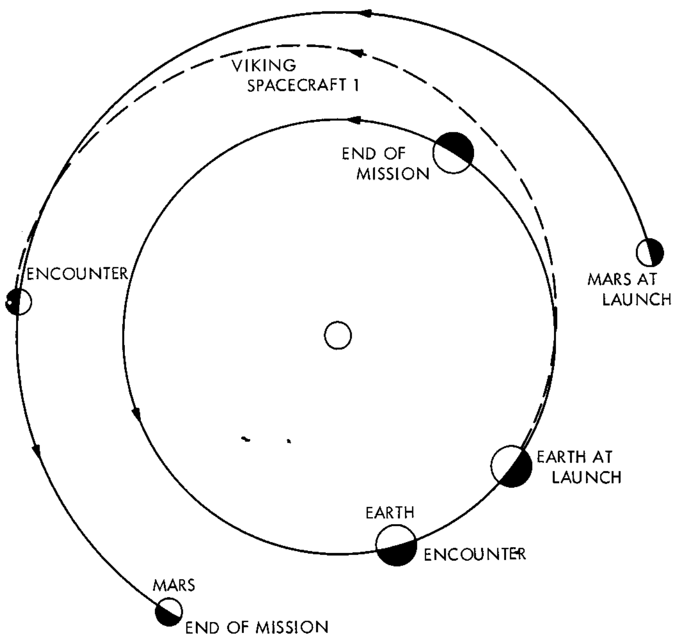

Fig. 2. Typical earth–Mars orbital projection

temperature and spreading of the telemetry modulation spectrum.

These effects first become significant about a month prior to conjunction when the sun–earth–Mars angle is about 8 to 9 deg. The way in which this affects the downlink telemetry link is discussed in detail in a subsequent article on the telecommunications problem.

VII. Near-Earth Phase Trajectories

The *Viking* mission utilizes a parking orbit ascent (*Titan III*) and two *Centaur* burns to inject the spacecraft into a Type II transfer orbit to Mars. The parking orbit is a 100-nmi circular orbit with a launch azimuth sector from 90 to 115 deg. The parking-orbit coast time is variable with a maximum coast time of 30 min.

For any given day the launch azimuths are variable and progressively increase, becoming more southerly the later the vehicle is launched during the daily window. The earth tracks for several representative Type II launch trajectories are shown in Fig. 5.

TDS development and analysis of these trajectories has been tabulated in Ref. 1, where view periods and other related data for supporting stations of the Air Force Eastern Test Range, the Manned Space Flight Network, and DSN may be found. This material forms the basis for all TDS planning in the near-earth phase.

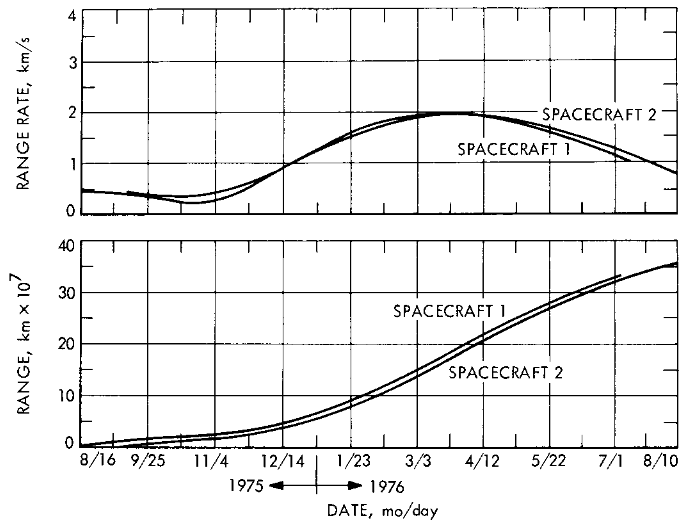

Fig. 3. Typical geocentric range and range rate

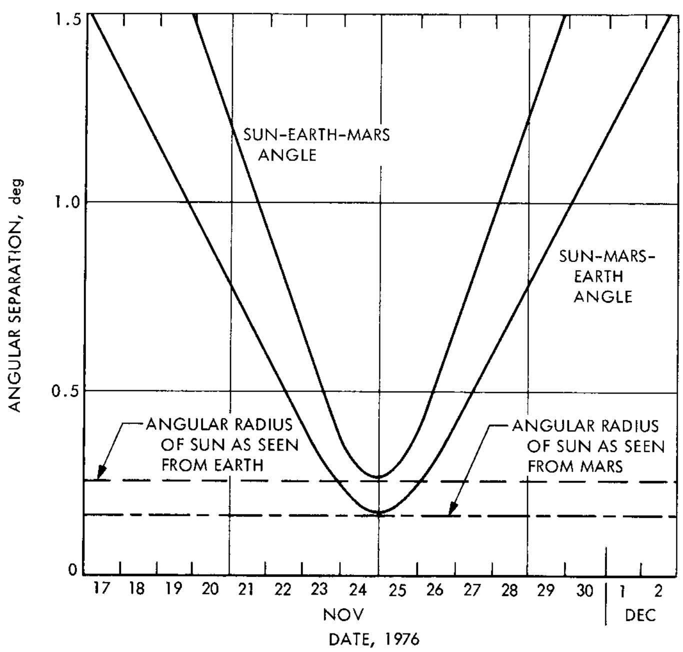

Fig. 4. Earth–Mars conjunction, November 1976

The problems facing the initial acquisition station of the DSN first become apparent as a result of these studies. Trade-offs are made between the need for good radiometric data at the earliest possible time after spacecraft separation, and the conflicting factors of high angle and doppler rates, and orbit uncertainties.

Depending on the parking orbit coast time for the actual trajectory selected at launch, either DSS 51 (short coast times) or DSS 42 (long coast times) will be used as the initial DSN acquisition station.

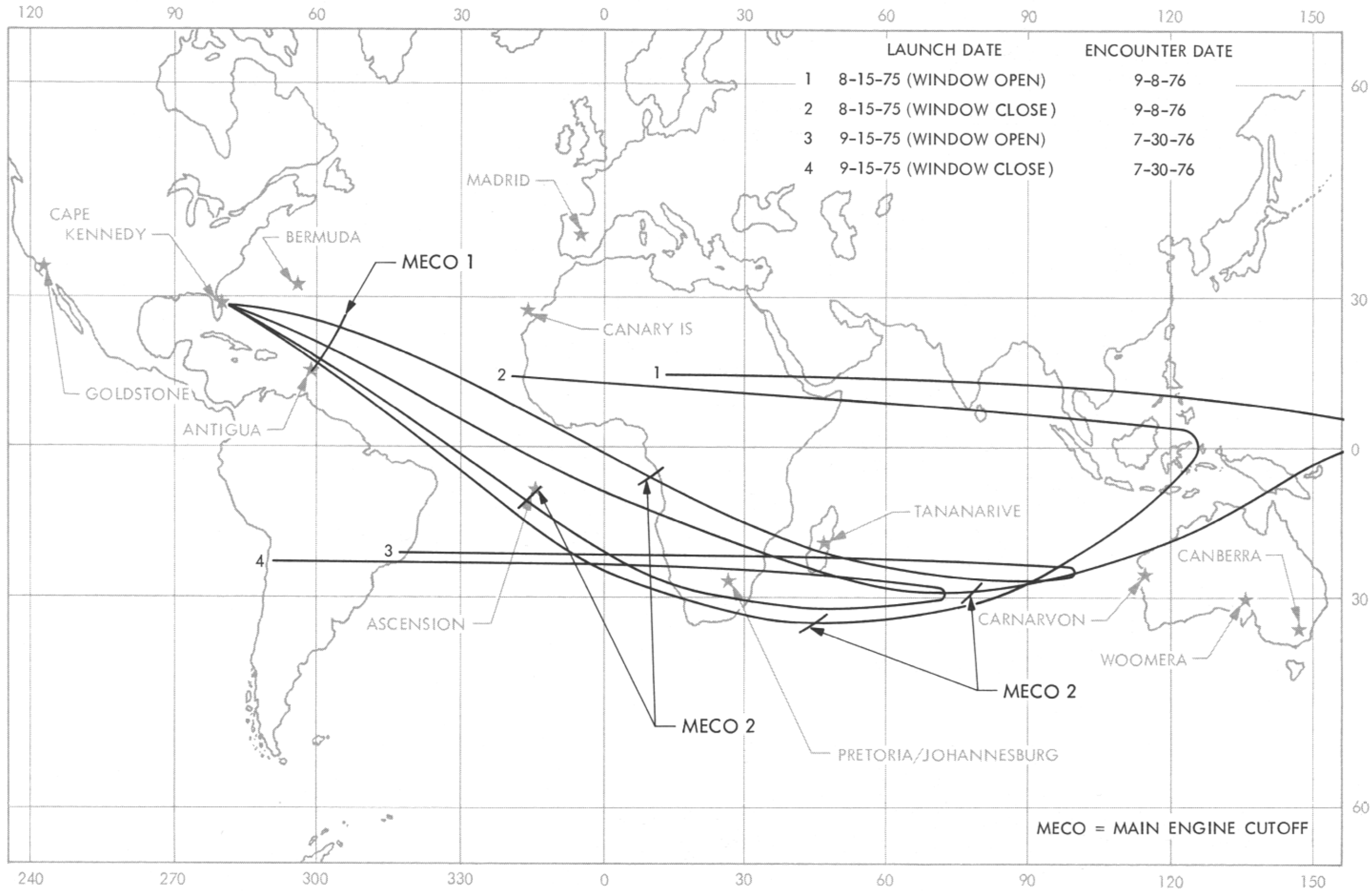

Fig. 5. ***Viking*** **Type II trajectory earth tracks**

Reference

1. Levy, H. N., Jr., *Viking Preliminary Near-Earth Phase Characteristics and Station Viewperiods* (JPL internal document), Sept. 4, 1970.